APPENDIX B

HEALTH AND ENVIRONMENTAL ASSESSMENT

B.1 HEALTH AND ENVIRONMENTAL ASSESSMENT

The Health and Environmental Assessment (HEA) is conducted to evaluate the impact of hazardous constituents present at a site. The HEA involves identifying the contaminants of concern, the concentrations of these compounds in the affected environmental media, and the risk to exposed or potentially exposed human or environmental receptors. The essential element of this assessment is the evaluation of health and environmental criteria to which the measured or predicted concentrations of toxic contaminants are compared. These criteria are primarily based on EPA established chronic exposure limits. When the criteria are exceeded, there is a likelihood of adverse health or environmental effects, and additional measures may be required to prevent or reduce these effects.

B.1.1 Identification of Toxic Contaminants

Analyses of soil samples from five boreholes located within the storage area for HF at LDU CPP-47 were conducted to determine the presence of unreacted hydrofluoric acid and fluoride in the soil. Boreholes CPP-47-02 and -03 were necessary to sample the soils that would have been directly under or proximal to the position where drums of HF acid were most likely situated. They are, therefore, logical sites for identification of soil contamination that may have occurred as a result of storage activities at LDU CPP-47. The analytical results are presented in Table 1.

Fluoride was detected at concentrations up to 240 mg/Kg in the soil. Fluoride toxicity is associated with any soluble fluoride compound that dissociates to produce fluoride ion (Gosselin et.al., 1984). The type and severity of toxicity varies with the chemical form, the route of exposure, and the duration of exposure. The potential for acute toxic effects from exposure to fluoride found in the soil is minimal since fluoride interacts with the environment and the soil to form relatively stable compounds. However, chronic effects from exposure to low doses of fluoride in these forms, through ingestion or occupational exposure to fluoride-containing dusts, can produce deposition of fluoride in the teeth (dental fluorosis) and the bone (skeletal fluorosis or osteosclerosis) (Baselt and Cravey, 1989). Fluoride is not known to be carcinogenic. Therefore, no determination of carcinogenic risk from possible exposure is applicable.

The form of fluoride that is most likely present at LDU CPP-47 is calcium fluoride because a bed of dolomite (calcium, magnesium carbonate) was placed under the pallets on which drums of HF were stored. Calcium fluoride is produced when HF is neutralized with limestone or dolomite. The relative toxicity of calcium fluoride is considered to be relatively minor because of the low solubility and low ionization of this salt (Gosselin et al., 1984). Chronic effects, however, may occur from the long-term ingestion of calcium fluoride or the inhalation of low levels of calcium fluoride dust.

B.1.2 Identification of Exposure Pathways

Soil samples were obtained at approximately the 0- to 1-, 1- to 2-, and 5- to 6-foot intervals from five boreholes located in the soil of the Pilot Plant HF Acid Storage Area. Although fluoride was detected at very low concentrations, the maximum (or near maximum) concentrations were detected in surface soils for all boreholes (see Table 1). The concentrations of fluoride are highest within the area defined by boreholes CPP-47-02 and CPP-47-03 and remain fairly constant with depth.

Exposure to fluoride in soils at LDU CPP-47 could occur via inhalation of dusts and vapors, ingestion, and dermal contact with soil. The significant exposure pathways for fluoride, however, will depend on the chemical form of the fluoride parent compound. The use of dolomite in the storage area suggests that the predominant form is calcium fluoride, a very stable compound with low solubility.

The inhalation pathway is considered inoperative because of the low concentrations of fluoride detected and the limited areal extent of contamination. Airborne particulates would exceed the National Ambient Air Quality Standard by several orders of magnitude before respirable fractions of airborne fluoride would pose a health risk. In addition, the extremely low vapor pressures of the fluoride compounds likely to occur in soils at LDU CPP-47 (as discussed below) preclude the vaporization of fluoride at air concentrations that would pose a health risk.

Due to the presence of fluoride in the surface soils, two pathways could potentially occur, including ingestion of fluoride-contaminated soil and dermal contact with soil. However, considering the chemical forms of fluoride in soil, the primary concern is with ingestion rather than dermal contact since the form of fluoride is calcium fluoride which is not a dermal contact risk.

HF may be present in the soils if complete neutralization did not occur (i.e., adequate amounts of dolomite were not available to completely neutralize spilled acid). The exposure routes of concern for this would be direct dermal contact with soils containing HF and inhalation of vapors which could be corrosive. However, given the approximately neutral pH determinations of the soil (6.73 - 7.47), it is highly unlikely that any HF would still be present in the soil.

Fluoride contamination patterns beneath LDU CPP-47 are more fully characterized when considered along with the pH analytical results. From Table 1 it can be seen that pH remains approximately neutral over the site for all depths of investigation. These results indicate that the natural pH buffering capacity of the soil and/or adequate quantities of dolomite were available to fully neutralize any spilled HF. Further, although fluoride levels in borehole CPP-47-02 remain fairly constant to depths of 6 feet, it is unlikely that significant quantities of fluoride have been transported to any great depth because of the following reasons:

- Relatively small volumes of moisture are available for transport of fluoride to the underlying soils and/or aquifers (Thomas, 1988, estimates an average annual recharge rate equal to 0.5 inches/year).

- In general, the greatest adsorption of fluoride by soils occurs at pH values of 6 to 7.

- Fluoride is known to readily replace hydroxyls of clays, particularly illites, which are known to occur in the alluvial material.

- In calcareous soils (i.e., Ca^{2+} provided by reaction with dolomite), the formation of slightly soluble fluorite (CaF_2) is favored (Kabata-Pendias, 1986).

In addition, the depth to groundwater, the lack of surface water bodies in the vicinity of the storage area, the apparently limited areal extent of associated contamination, and the low concentrations of contaminants detected preclude any significant impact on water from LDU CPP-47. Thus, neither surface water nor groundwater is considered as a potential exposure pathway.

B.1.3 Identification of Receptor Populations

The ICPP is a secured industrial site with limited access. The most likely receptors for contaminants present at LDU CPP-47 are workers with direct access to the soil in the immediate vicinity of the Pilot Plant Storage Area.

B.1.4 Human Health Assessment

As discussed in Section B.1.2, the surficial soils would tend to fix fluoride in some mineral form (e.g., fluorite, CaF_2), and in so doing, the workers at the ICPP could be exposed to the contaminants through incidental soil ingestion or dermal contact, the two potentially operative exposure pathways. The maximum concentration of fluoride detected at LDU CPP-47 (240 mg/Kg) was identified in surface soils. Consequently, this concentration is used to assess the potential human health effects from potential fluoride exposure. The results of the assessment are summarized in Table B-1.

Fluoride is known to have systemic toxic effects if exposures are great enough. The soil concentrations, if ingested, that would result in an oral dose equivalent to the applicable chronic reference dose (RfD) for fluoride were calculated as part of the assessment. The RfD for a contaminant is the daily intake of the contaminant to which even a sensitive individual might be exposed without developing associated critical toxic effects. The following screening has been conducted in accordance with the RCRA Facility Investigation Guidance (EPA, 1989b) and the proposed rule for Corrective Action for Solid Waste Management Units at Hazardous Waste Management Facilities (FR Vol. 55, No. 145 30798-30884).

The equation for calculating the soil screening criterion is given below.

$$CS = \frac{RfD \times BW}{IR \times CF}$$

where:

CS = Soil concentration screening criterion
RfD = Chronic Reference Dose
BW = Body Weight (16 kg)
IR = Ingestion Rate (200 mg/day)

CF = Conversion Factor (1E-06 kg/mg)

None of the soil concentrations detected exceed the maximum allowable soil concentrations based on the RfD (see Table B-1). Therefore, systemic adverse health effects should not occur in even sensitive individuals exposed to soil contaminants at the levels detected in the soils at LDU CPP-47.

It should be noted that two screening criteria are provided for fluoride. An RfD of 0.06 mg/Kg/day is published that reflects the level of exposure children may have without developing dental fluorosis from an excess intake of fluoride (EPA, 1991). This effect is considered a cosmetic effect rather than an adverse or toxic health effect. A second intake level based on an adverse health effect in adults (skeletal fluorosis) is also reported in the Integrated Risk Information System (EPA, 1991) and is presented in Table B-1. The soil concentrations of fluoride found at LDU CPP-47 do not exceed the screening criteria corresponding to either of these acceptable intake levels for fluoride and, in fact, are at least an order of magnitude less than either soil screening criterion.

For the levels of fluoride detected, the contribution of dermal contact to the overall health risk, although not quantitatively evaluated, would be inappreciable because of the low levels of soil contamination and the relatively small area of soil contamination.

Based on the results of the screening presented above, adverse health impacts to workers in the vicinity of or with direct access to LDU CPP-47 would not occur from the contaminant concentrations detected.

TABLE B-1

SUMMARY OF HEALTH AND ENVIRONMENTAL ASSESSMENT FOR LDU CPP-47

Constituent	Maximum Detected Soil Concentration (mg/Kg)	Screening Criteria	
		Chronic Oral RfD (mg/Kg/d)	Soil Concentration = RfD (mg/Kg)
Fluoride	240	6E-02[a,b] 1.2 E-01[c]	4800 230,000[d]

(a) EPA 1991

(b) Critical effect considered cosmetic rather than an adverse/toxic health effect

(c) Calculated safe exposure level in adults to prevent skeletal fluorosis (EPA 1991)

(d) Assumed Industrial Scenario: 100 mg/d soil ingestion, 36% frequency, 40 year exposure, 70 kg body weight

B.1.5 Environmental Assessment

LDU CPP-47 is located within the controlled boundaries of the ICPP and was formerly the site of a storage area for HF acid. Fluoride was found in soils at all depths of investigation; however, concentrations were maximum in surface soils of the storage area where HF drums had been situated. LDU CPP-47 does not support any vegetation with roots extending into the area of detected contamination. Large animals and migratory wildlife have no access to or are not known to frequent the immediate area surrounding LDU CPP-47. Consequently, no adverse impact on terrestrial biota should occur.

Surface water and groundwater will not be adversely impacted by the levels of soil contamination detected at LDU CPP-47. Low annual rainfall will result in little surface runoff and infiltration. These conditions, in addition to the depth to groundwater (approximately 450 feet) and low level of soil contamination, will limit migration of fluoride and any adverse effects on surface waters or groundwater in the vicinity of LDU CPP-47.

Impacts on downwind environments from airborne dispersion and diffusion of contaminants will be insignificant because of the low soil contaminant concentrations, extremely low vapor pressures typical of solid-phase fluoride compounds, and the limited area of contamination.

APPENDIX C

QUALITY ASSURANCE SAMPLE
ANALYSIS RESULTS
AND LABORATORY SUMMARY RESULTS

TABLE C-1

FIELD DUPLICATE ANALYSIS RESULTS
LAND DISPOSAL UNIT CPP-47

Sample ID: CPP-47-02-1
CPP-47-02-1FD

Analyte/Compound	Initial Result	Duplicate Result	Relative Percent Difference
Fluoride	196	193	2
pH	7.17	7.11	1

U - Compound not detected; the reported value is the sample detection limit.

NC - Result not calculable due to one or both values below the sample detection limit or not detected.

TABLE C-2

INORGANIC ANALYSIS RESULTS
LAND DISPOSAL UNIT CPP-47

Borehole	Depth (feet)	Fluoride (mg/Kg)	pH
CPP-47-01	1	6.77	6.73
CPP-47-01	2	8.32	7.45
CPP-47-02	1	196	7.17
CPP-47-02	2	121	7.25
CPP-47-02	6	197	7.23
CPP-47-03	1	240	7.15
CPP-47-03	2	189	7.36
CPP-47-04	1	5.04	7.38
CPP-47-04	2	3.50	7.45
CPP-47-04	4	5.53	7.14
CPP-47-05	1	13.6	7.40
CPP-47-05	2	8.31	7.46
CPP-47-05	5	1.63	7.47
Maximum Value		240	7.47
Minimum Value		1.63	6.73
Contract Required Quantitation Limit		0.33	N/A
Background UTL		6.55	N/A

INORGANIC ANALYSIS REPORT

Client Sample ID	CPP-47-01-1	CPP-47-01-2	CPP-47-02-1	CPP-47-02-1-FD
PNELI Sample ID	2908-01	2908-02	2908-03	2908-04
Sample Matrix	Soil	Soil	Soil	Soil
Date Sample Received	01-31-91	01-31-91	01-31-91	01-31-91
Date Sample Analyzed	01-31-91	01-31-91	01-31-91	01-31-91
Units of Measure (no units for soil pH)	mg/kg	mg/kg	mg/kg	mg/kg

Compound				
Soil pH measured in 0.01M$CaCl_2$	6.73	7.45	7.17	7.11
Soluble Fluoride	6.77	8.32	196	193

Client Sample ID	CPP-47-02-1-EB	CPP-47-02-2	CPP-47-02-6	CPP-47-03-1
PNELI Sample ID	2908-05	2908-06	2908-07	2908-08
Sample Matrix	Water	Soil	Soil	Soil
Date Sample Received	01-31-91	01-31-91	01-31-91	01-31-91
Date Sample Analyzed	01-31-91	01-31-91	01-31-91	01-31-91
Units of Measure (no units for pH or soil pH)	mg/ℓ	mg/kg	mg/kg	mg/kg

Compound				
pH	5.21	—	—	—
Soil pH measured in 0.01M$CaCl_2$	—	7.25	7.23	7.15
Fluoride	0.100 U	—	—	—
Soluble Fluoride	—	121	197	240

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INORGANIC ANALYSIS REPORT

Client Sample ID	CPP-47-03-2	CPP-47-04-1	CPP-47-04-2
PNELI Sample ID	2908-09	2908-10	2908-11
Sample Matrix	Soil	Soil	Soil
Date Sample Received	01-31-91	01-31-91	01-31-91
Date Sample Analyzed	01-31-91	01-31-91	01-31-91
Units of Measure (no units for pH or soil pH)	mg/kg	mg/kg	mg/kg

Compound			
pH	—	—	—
Soil pH measured in $0.01 M CaCl_2$	7.36	7.38	7.45
Fluoride	—	—	—
Soluble Fluoride	189	5.04	3.50

Client Sample ID	Blank	Blank
PNELI Sample ID	2908-MB	2908-MB
Sample Matrix	Soil	Water
Date Sample Received	NA	NA
Date Sample Analyzed	01-31-91	01-31-91
Units of Measure	mg/kg	mg/ℓ

Compound		
Fluoride	—	0.100 U
Soluble Fluoride	0.500 U	—

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INORGANIC ANALYSIS REPORT

Client Sample ID	CPP-47-04-4	CPP-47-05-1	CPP-47-05-2	CPP-47-05-5
PNELI Sample ID	2911-01	2911-02	2911-03	2911-04
Sample Matrix	Soil	Soil	Soil	Soil
Date Sample Received	02-01-91	02-01-91	02-01-91	02-01-91
Date Sample Analyzed				
Soil pH	02-04-91	02-04-91	02-04-91	02-04-91
Soluble Fluoride	02-05-91	02-05-91	02-05-91	02-05-91
Units of Measure (no units for soil pH)	mg/kg	mg/kg	mg/kg	mg/kg

Compound				
Soil pH measured in 0.01M$CaCl_2$	7.14	7.40	7.46	7.47
Soluble Fluoride	5.53	13.6	8.31	1.63

Client Sample ID	Blank
PNELI Sample ID	2911-MB
Sample Matrix	Soil
Date Sample Received	NA
Date Sample Analyzed	02-05-91
Units of Measure	mg/kg

Compound		
Soluble Fluoride	0.500	U

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INORGANIC DUPLICATE ANALYSIS REPORT

Client Sample ID: CPP-47-01-1
Sample Matrix: Soil
Units of Measure: mg/kg
(no units for soil pH)

PNELI Sample ID: 2908-01
Date Sample Received: 01-31-91

Analyte	Duplicate Sample Concentration	Original Sample Concentration	Relative % Difference
Soil pH measured in 0.01M$CaCl_2$	6.93	6.73	2.93
Soluble Fluoride	8.18	6.77	18.9

Client Sample ID: CPP-47-02-1-EB
Sample Matrix: Water
Units of Measure: mg/ℓ
(no units for pH)

PNELI Sample ID: 2908-05
Date Sample Received: 01-31-91

Analyte	Duplicate Sample Concentration	Original Sample Concentration	Relative % Difference
pH	5.26	5.21	0.955
Fluoride	0.100 U	0.100 U	NC

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INORGANIC DUPLICATE ANALYSIS REPORT

Client Sample ID: CPP-47-04-4

Sample Matrix: Soil

Units of Measure: mg/kg
(no units for soil pH)

PNELI Sample ID: 2911-01

Date Sample Received: 02-01-91

Analyte	Duplicate Sample Concentration	Original Sample Concentration	Relative % Difference
Soil pH measured in 0.01M$CaCl_2$	7.27	7.14	1.80
Soluble Fluoride	7.17	5.53	25.8

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INORGANIC MATRIX SPIKE ANALYSIS REPORT

Client Sample ID: CPP-47-04-4
PNELI Sample ID: 2911-01
Sample Matrix: Soil
Date Sample Received: 02-01-91
Units of Measure: mg/kg

Analyte	Spike Sample Concentration	Original Sample Concentration	Spike Level	Percent Recovery
Soluble Fluoride	24.4	5.53	5.54	341

Client Sample ID: Method Blank
PNELI Sample ID: 2911-MB
Sample Matrix: Soil
Date Sample Received: NA
Units of Measure: mg/kg

Analyte	Spike Sample Concentration	Original Sample Concentration	Spike Level	Percent Recovery
Soluble Fluoride	4.61	0.500 U	5.00	92.2

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INORGANIC MATRIX SPIKE ANALYSIS REPORT

Client Sample ID: CPP-47-01-1
Sample Matrix: Soil
Units of Measure: mg/kg

PNELI Sample ID: 2908-01
Date Sample Received: 01-31-91

Analyte	Spike Sample Concentration	Original Sample Concentration	Spike Level	Percent Recovery
Soluble Fluoride	11.1	6.77	4.69	92.3

Client Sample ID: CPP-47-02-1-EB
Sample Matrix: Water
Units of Measure: mg/ℓ

PNELI Sample ID: 2908-05
Date Sample Received: 01-31-91

Analyte	Spike Sample Concentration	Original Sample Concentration	Spike Level	Percent Recovery
Fluoride	0.911	0.100 U	1.00	91.1

Client Sample ID: Blank
Sample Matrix: Soil
Units of Measure: mg/kg

PNELI Sample ID: 2908-MB
Date Sample Received: NA

Analyte	Spike Sample Concentration	Original Sample Concentration	Spike Level	Percent Recovery
Soluble Fluoride	4.54	0.500 U	5.00	90.8

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APPENDIX D

COMPLETE LIST OF COMPOUNDS ANALYZED

TABLE D-1

TARGET COMPOUND/ANALYTE LIST
LAND DISPOSAL UNIT CPP-47

CONSTITUENT
pH
INORGANICS
Fluoride

APPENDIX E

TP-1.2-5, Technical Procedure
Drilling, Sampling, and Logging of Soils

1. PURPOSE

The purpose of this technical procedure is to establish uniform and consistent methods for drilling, sampling, and logging soils. This technical procedure also establishes a uniform methodology for collecting representative soil samples for chemical analysis.

2. APPLICABILITY

This technical procedure is applicable to all Golder Associates Inc. representatives engaged in subsurface soils investigations. It may be used at either uncontaminated or contaminated sites. This procedure includes, as an option, the use of inner barrel liners.

3. DEFINITIONS

3.1 Breaking Drill Rod

Breaking drill rod is defined as withdrawing and decoupling drill rod in order to advance the boring, retrieve samples, or abandon the hole.

3.2 Down Time

Down time is defined as non-productive time due to a drilling contractor's operational problems.

3.3 Contaminated Site

A contaminated site is defined as a location at which an environmental investigation is being conducted for the purpose of determining the existence or extent of hazardous waste/substances or groundwater contamination.

3.4 Inner Barrel Liner

An inner barrel liner is defined as an insert installed in the sampling tool to contain soil materials. The liner is generally made of Lexan or a fiber/composite material, is available in lengths of 6" to 5' and is designed to fit snugly inside the sampling tool (e.g., split-spoon sampler).

3.5 In Situ Soil Sample

An in situ soil sample is, a (theoretically) undisturbed sample which represents the soil as it exists in the ground. Although all samples are disturbed to a certain extent, in situ sampling methods attempt to minimize disturbance.

3.6 Engineering/Geologic Soil Sample

An engineering/geologic soil sample is defined as soil acquired from a borehole for geotechnical or geological analysis or interpretation.

3.7 Environmental Soil Sample

An environmental soil sample is defined as soil acquired from a borehole for chemical analysis that is representative of the soil as it exists in the ground.

3.8 Sample Bottles

Sample bottles are containers specifically designed and prepared for storing soils samples. Sample bottle type, material, size and type of lid are specific for particular tests or groups of analytes. Sample bottles for storing soils which will be chemically analyzed must be properly cleaned and prepared by a laboratory or the manufacturer in accordance with Reference 4.6.

3.9 In Situ Soil Testing

In situ soil testing is performed on the soil at its naturally existing location or interval; examples include cone penetrometer, standard penetration, and in situ vane shear testing.

3.10 Production Time

Production time is defined as the time spent performing contractually required activities under the drilling contract other than drilling. An example might be the time spent installing piezometers.

3.11 Stand-by Time

Stand-by time is defined as non-productive time due to the Golder Associates Geologist/Field Engineer halting work.

3.12 Subcoring

Subcoring is defined as the collection of a core from within a core. Subcoring is used to help minimize borehole cross-contamination of sample material.

3.13 Subsurface Investigation

A subsurface investigation is defined as the exploration of the soil stratigraphy, groundwater and other characteristics below the earth's surface; investigative techniques typically include drilling and sampling and excavation of test pits; test pitting is addressed in TP-1.1-3, "Test Pit Logging and Sampling."

4. REFERENCES

4.1 Golder Associates Technical Procedure TP-1.2-6, "Field Identification of Soils"

4.2 Golder Associates Technical Procedure TP-1.2-23 "Chain of Custody"

4.3 ASTM-D-1586, "Penetration Test and Split-Barrel Sampling of Soils"

4.4 ASTM-D-1587, "Standard Practice for Thin-Walled Tube Sampling of Soils"

4.5 ASTM-D-3550, "Ring-Lined Barrel Sampling of Soils"

4.6 USEPA, 1986 Test Methods for Evaluating Solid Waste (SW-846), US EPA/Office of Solid Waste, Washington, D.C.

4.7 USEPA, 1989 Soil Sampling Quality Assurance User's Guide, 2nd Edition, USEPA/Environmental Monitoring Systems Laboratory, Las Vegas, NV.

5. DISCUSSION

The purpose of any drilling and sampling program is to obtain information which will be used in evaluation of the characteristics and conditions of a particular site. The quality of any design or assessment hinges on the quality of the samples obtained and the data derived from them. Specified guidelines and procedures for drilling operations, sampling, and logging must be followed in order to obtain uniformly useful samples. It is the Project Manager's responsibility to design the drilling and sampling program for the project, and to select the drilling and sampling techniques to be used for achieving project objectives. Standard drilling techniques are included in Appendix A, and sampling techniques in Appendix B. It is the Geologist/Field Engineer's responsibility to see that samples are obtained in compliance with the defined methods, and that accurate and complete drilling data is recorded. Drilling data should include the soil types and conditions encountered during drilling, and any variations from prescribed drilling and sampling standards. All variations must be documented on Procedure Alteration Checklists (Exhibit F) and approved by the Project Manager and Quality Assurance (QA) Manager. Standard forms used for recording drilling and sampling information are the History of Hole form (Exhibit A) and the Record of Borehole log (Exhibit B). Samples shall be labeled, stored and transported as appropriate for the sample type and subsequent testing or analysis.

For the collection of environmental soil samples, all sampling equipment shall be decontaminated before and after each use. If directed by the Project Manager or as specified in project work documents, soil and decontamination fluids shall be captured and contained for disposal. Samples shall be collected in properly prepared containers of the appropriate size and type. All samples shall be appropriately labelled and sealed (see Exhibit E). Environmental samples shall be stored and transported in coolers at 4°C. Chain of Custody (Exhibit D) shall be maintained in accordance with procedure TP-1.2-23, "Chain of Custody." The History of Hole form (Exhibit A) and Sample Integrity Data Sheet (see Exhibit C) shall be used to document daily site activities and sample collection. All variations from established procedure shall be documented on the Procedure Alteration Checklist (see Exhibit F) and shall be approved by the QA Manager and the Project Manager.

Field personnel must understand the purpose and goals of their efforts in order to make appropriate judgement calls. It is the responsibility of the Project Manager to make this information available to the Geologist/Field Engineer, just as it is the responsibility of the Geologist/Field Engineer to make every effort to fully understand the purpose of the task.

6. RESPONSIBILITIES

6.1 Project Manager

The Project Manager is responsible for the overall management of the drilling and sampling project, but may delegate responsibilities to other qualified team members. Duties include design of the drilling and sampling program, location of boreholes, establishing minimum sampling frequency and sampling techniques, approving all variations from established procedures, ensuring that contractual agreements are established with the contractors, preparing the scope of work, and briefing all field personnel on the expectations and requirements peculiar to the project. The Project Manger may assume the responsibilities of the Task Leader on small projects.

6.2 Task Leader

The Task Leader is responsible for supervising the Geologist/Field Engineer. Supervision includes ensuring that samples are collected, documented, logged, handled and shipped to the appropriate laboratory as specified in project work documents and this technical procedure.

6.3 Geologist/Field Engineer

The Geologist/Field Engineer is responsible for documenting all on-site geotechnical activity. These activities include: ensuring that samples of adequate quality are obtained in a manner consistent with this procedure, documenting variations from standard procedures, logging samples, ensuring sample integrity in storage and transportation to the laboratory for testing, and reviewing the daily drilling report with the drilling contractor. The Geologist/Field Engineer shall develop an understanding of the ultimate goal of the investigation in order to adequately record needed information and be able to make sound decisions in case of unforeseen circumstances.

6.4 Document Custodian

The document custodian is responsible for maintaining project files and filing project documents, project correspondence, sample integrity data sheets, chain of custody forms, field report forms, other forms, generated data and other associated and pertinent project information.

6.5 Quality Assurance Manager

The QA Manager is responsible for approving Procedure Alteration Checklists.

7. EQUIPMENT OR MATERIALS

7.1 Contractor-Supplied Equipment

The following equipment is typically supplied by the drilling contractor; actual requirements shall be as specified in the scope of work established by the Project Manager.

- Drill rig and all drilling tools, rods, bits, water tank, and related equipment.

- Sampling tools, such as spilt-tube samplers and bailers.

- Portable steam cleaners for cleaning environmental sampling equipment, the drilling and other drilling equipment are generally required in investigations of potentially contaminated sites, and may be provided by the drilling contractor or rented separately.

- Container(s), 55-gallon steel drums, as required for containing drill soil cuttings and decontamination fluids.

- Shelby tubes and caps.

7.2 Golder Associates Supplied Equipment

7.2.1 General Field Supplies

Supplies required for Golder Associates field personnel generally include the following:

- Technical Procedures Field Book
- Health and Safety Plan
- Knife or spatula
- Indelible ink pens and felt tip markers
- Shipping containers
- Procedure Alteration Checklists (Exhibit F)
- History of Hole Forms (Exhibit A)

- Record of Borehole Logs (Exhibit B)
- Sample jars or bags
- Sample labels (Exhibit E)
- Folding rule
- Clipboard
- Engineering tape measure
- Flagging
- Golder staff telephone list
- Other items as dictated by project need

7.2.2 Field Supplies for Environmental Sampling

Additional items needed for acquiring environmental soil samples at a potentially contaminated site shall be as specified by the Project Manager and/or site health and safety plans, and may include the following:

- Site Sampling Plan, Work Plan and Health and Safety Plan (HASP)
- Cooler for sample transport, with "blue ice" or ice bags
- Appropriate sample Jars for planned testing or analyses (See Table 1)
- Sampling equipment such as scoops or spatulas. All equipment shall be stainless steel or teflon
- Organic Vapor Analyzer (OVA), OVM, TIP, H_2S meter or combustible gas detector with accessories and calibration gases (Optional depending on HASP requirements)
- Chain of Custody (Exhibit D)
- Sample Integrity Data Sheet (Exhibit C)
- Sample Labels and Seals (Exhibit E)
- Cleaning equipment and solutions
- Container(s) for capturing, containing and treating waste documentation solutions, if necessary
- Organic free distilled or deionized water
- Protective clothing and equipment as required by the HASP.

8. PROCEDURE

8.1 General Considerations

8.1.1 Project Briefing and Site Preparation

The Project Manager shall ensure that all Golder Associates and Contractor personnel are briefed on the importance of proper drilling and sampling techniques, decontamination procedures, health and safety requirements, and the other issues addressed by this technical procedure. All sampling activities shall comply with the individual work plans and the site Health and Safety Plan (HASP) requirements. All personnel shall be advised that unanticipated conditions may dictate changes in standard and accepted procedures as outlined in this technical procedure. All such variations shall be documented on a Procedure Alternation Checklist (Exhibit F) and reviewed and approved as noted in Section 8.2.7 below.

All downhole drilling and sampling equipment shall be measured for correct length prior to use for the purpose of accurately measuring depth during drilling. Measurements shall be recorded by the Geologist/Engineer. All sampling equipment used to collect environmental soil samples shall be decontaminated prior to being used to collect a sample. Drilling equipment used to collect environmental soil samples must be decontaminated prior to being used on each borehole. Engineering/geologic soil samples will generally require no decontamination of samplers and drilling equipment.

8.1.2 Decontamination of Environmental Sampling and Drilling Equipment

For environmental sampling investigations, sampling and drilling equipment must be thoroughly cleaned to avoid cross-sample contamination. Environmental soil sampling devices must be decontaminated prior to obtaining each sample; drilling equipment must be decontaminated prior to use on each borehole. Unless specified otherwise in project plans, tools and equipment shall be decontaminated by steam cleaning and/or by washing with a non-phosphate detergent and rinsing with distilled water. For inorganic analytes, a weak hydrochloric acid (HCl) solution shall be used for the second wash. For organic analytes, reagent grade methanol shall be used for the second wash. A final rinse with organic-free distilled/deionized water shall complete the decontamination. Wash and rinse fluids shall be collected; responsibility for disposal shall be defined in the governing project plans. Decontamination procedures shall be recorded by the Geologist/Engineer. The Geologist/Engineer shall be responsible for inspecting all decontaminated equipment to insure that decontamination procedures have been adequate.

8.1.3 Sample Quantities and Types

Samples shall be collected in quantities and types as directed by the Project Manager or as specified in the project work documents. The Record of Borehole Log (Exhibit B) and the Sample Integrity Data Sheet (Exhibit C) shall be used to document daily site activities and sample collection. Environmental samples shall be transferred to the analytical laboratory under formal Chain of Custody (Exhibit D), which shall be documented and maintained in accordance with procedure TP-1.2-23, "Chain of Custody."

8.1.4 Sample Containers

The type of sample containers shall be specific to the needs of the project and shall be determined by the Project Manager. Sample containers for environmental soil samples are very specific and vary greatly from those used routinely to collect geotechnical/geologic samples. They may be wide mouth glass jars with teflon lined caps for potentially contaminated samples, or plastic jars for standard archived soil samples. Plastic bags may be used in some cases. The acceptable material for environmental soil sample containers depends on the planned analyses and is addressed in Table 1.

If an inner barrel liner is used, it may not be necessary to remove the sample material for transfer to a sample container. If liners are used for environmental samples, the sample material is left relatively undisturbed and the liner is sealed with teflon sheeting or aluminum foil and covered with plastic caps, then sealed with tape. If liners are used for geotechnical soil testing, wax may be used as a seal directly in contact with the sample (replacing the teflon sheeting or aluminum foil). The liner shall be labeled in compliance with Section 8.2.3 and permanently marked to indicate sample orientation in the borehole. Unfilled end sections of liners for geotechnical samples should be removed with a hacksaw or cutoff saw prior to capping and sealing, in order to prevent disturbance of core material. In the event that the Project Manager requires subcoring of samples in inner liners, either extract sample material from the center of the core without disturbing material on the liner sidewalls, or use a small diameter shelby tube and hydraulic press to collect a subcore from the interior portion of the liner sample.

8.2 Documentation

Documentation for sampling soils includes labelling sample bottles; and may include depending on the type of sample completing History of Hole forms, Record of Borehole logs, Sample Integrity Data Sheets, and Chain of Custody Records; and, securing individual samples or sample coolers with chain of custody seals. The original field forms shall be submitted as soon as possible to the Document Custodian for filing. Copies shall be given to the Project Manager and Task Leader.

8.2.1 History-of-Hole Forms

A record of events related to each borehole shall be maintained by the Geologist/Field Engineer on the History of Hole form (Exhibit A). The purpose of this form is to document events associated with drilling each hole in case questions arise later. All events which could affect the successful and timely completion of a borehole should be recorded with the time interval the event occurred. All information available prior to the initiation of drilling a borehole should be recorded, including job number and location; borehole number; name of contractor, driller, and Geologist/Field Engineer; weather conditions; and temperature. Other data requested on the form shall be completed as it becomes available.

The names and responsibilities of people working at or visiting the site should be recorded, as well as the time of their arrival and departure. Other items that should be noted include the shift time, beginning and end of drilling or production time, down time, stand-by time, total footage drilled, quantities of supplies used (i.e., sand, grout, piezometer piping, etc.), depth water was encountered, and the number and type of samples taken.

8.2.2 Record of Borehole Log

The Record of Borehole log (Exhibit B) provides both a graphic and descriptive record of subsurface observations made during the drilling of the borehole. All immediately available information shall be filled out first; including borehole number, drilling date, drill rig, job number, contractor's name, driller's name, and Geologist/Field Engineer's name. Other information, such as elevation and location coordinates may be added later if they are not immediately known. The log may be modified by the Project Manager to include information such as station number, OVA scans, offset distance, and inclination of hole, to suit the needs of a particular project. Minor variations to this log have been used in the past and may be preferred for consistency for a particular client.

A scale which will allow enough space for soil descriptions shall be chosen and recorded in the first column under the heading "Depth Scale" starting at 0 feet. This scale shall be used to align the information across the form so that data can be easily related to the proper depth at which it was encountered. The method of drilling shall be recorded in the next column, marking the appropriate depths that the method was used. The next 3 columns (Soil Profile Description, Graphic Log, and USCS) may be left blank until the type of material has been determined and a change in soil type has been encountered. The Geologist/Field Engineer shall observe the soil cuttings coming out of the hole to make an approximation of depth of change. This may be verified by comparing samples on either side of the change. Top and bottom depths of each soil horizon shall be noted in the "Soil Profile Description" column, followed by a description of the material. A pictorial representation of the zone shall be sketched in the "Graphic Log" column, and material designation according to the Unified Soils Classification System (see Golder Associates TP-1.2-6) be placed in the "USCS" column. A line shall be drawn across these 3 columns corresponding to the top and bottom depths on the Depth Scale. A straight line across the Graphic Log column represents a known depth of change, while a slanted line represents an approximate depth.

The sample number, type of sample taken, blow count, and percent recovery shall be recorded in the appropriate columns at the corresponding scaled depths. Lines shall be sketched across these columns to show top and bottom of the sample. Blow counts, if required, will be taken during Standard Penetration Tests (SPT), and shall be recorded for every 6 inches in an 18 inch sample. The percent recovery shall be recorded as a fraction, i.e., the number of inches recovered over the number of inches sampled. If a non-standard drive tube sampler or drive force is used, record the details associated with the penetration tests.

Each sample shall be described according to TP-1.2-6 and recorded in the Sample Description column. The sample number should be recorded first, followed by the sample interval depth, and then the description. An effort should be made to line the descriptions up with the corresponding scaled depth; however, it is much more important that all pertinent information be recorded. This column is also the appropriate place to make notes which may prove to be important in the later analysis, such as the depth of the water table, definite changes in drilling speed, unexpected materials or odors coming up with the cuttings, chemical staining, OVA or OVM scans of samples or excessive jarring of the sample.

In the event that a piezometer or monitoring well is installed in the hole, a graphic representation of the installation may be drawn showing the bottom of the casing in relationship to the bottom of the hole, screened zones, bentonite seals, sand back fill, and other back fill zones if applicable. Piezometers and monitoring wells shall be constructed in accordance with applicable Golder Associates technical procedures and governing state regulations.

8.2.3 Sample Labels

Samples shall be immediately labelled (see Exhibit E for an example label(s)). Labels shall be water proof. Information shall be recorded on each label with indelible ink. All blanks shall be filled in (N/A if not applicable). Soil sample designations will be as specified in the project work documents or by the Project Manager.

8.2.4 Sample Integrity Data Sheets

Sample Integrity Data Sheets (Exhibit C) are used by the Geologist/Field Engineer to document the official raw field information for each environmental sample that will be chemically analyzed. All blanks shall be filled in (N/A if not applicable).

8.2.5 Chain of Custody Records

Chain-of-Custody Records (Exhibit D) will be used to record the custody and transfer of environmental samples in accordance with procedure TP-1.2-23, "Chain of Custody." These forms shall be filled in completely (N/A if not applicable). Tamper-proof Seals (Exhibit E) shall be placed on either sample bottles or shipping coolers in a manner such that accessing a sample will break the seal. The seal number shall be recorded on the Chain of Custody Form. The original form must accompany the samples to the analytical laboratory to be completed and returned to Golder for filing by the Document Custodian. A copy of the Chain of Custody Record documenting the transfer of samples from the field shall be submitted to the Document Custodian for filing.

8.2.6 Procedure Alteration Checklist

Variation from established procedure requirements may be necessary due to unique circumstances encountered on individual projects. All variations from established procedures shall be documented on Procedure Alteration Checklists (Exhibit F) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize individual Geologist/Field Engineers to initiate variations as necessary. If practical, the request for variation shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented immediately at the direction of the Geologist/Field Engineer, provided that the Project Manager is notified of the variation within 24 hours of implementation, and the Procedure Alteration Checklist is forwarded to the Project Manager and QA Manager for review within 2 working days of implementation. If the variation is unacceptable to either reviewer, the activity shall be reperformed or action shall be taken as indicated in the Comments section of the checklist.

All completed Procedure Alteration Checklists shall be maintained in project records.

8.3 Soil Sample Acquisition

8.3.1 Drilling Methods

Many types of drilling methods exist for the purpose of advancing boreholes through soil or other unconsolidated deposits. Unconsolidated deposits present special drilling problems due to the nature of the material, specifically a tendency to collapse. The Project Manager shall determine the most appropriate technique for the types of material expected to be encountered. The most commonly used methods include hollow stem augering, air or mud rotary drilling, and cable tool drilling. Drilling methods are discussed in detail in Appendix A.

8.3.2 Sampling Considerations

Sampling shall start at the ground surface and continue at depth intervals as specified in the project work plan or as directed by the Project Manager. Unless otherwise directed by the Project Manager, drill sample cuttings from rotary drilling rigs shall be obtained at the surface and at 5 feet depth intervals or in each distinct stratum. For auger drilling rigs, drive tube samples shall be collected at 5 feet depth intervals. Additional environmental soil samples (in addition to specified samples in project plans) may be collected in strata where contaminants potentially could accumulate.

The sampler shall be removed from the hole avoiding excess jarring to the sampler when breaking the drill rods, as such jarring may result in loss of all or a portion of the sample. Excess jarring also disturbs the integrity of samples intended to be undisturbed samples, making test results on soil strengths erroneous. Excess jarring of in situ samples should be noted on the Record of Borehole (Exhibit B).

Procedures for managing poor recovery shall be established with the Project Manager prior to initiating drilling and sampling activities. If a sample is lost or poor recovery is realized (defined as more than 50 percent missing from the sampled length), the following minimum procedures shall be followed:

1) The Geologist/Field Engineer shall confirm that the appropriate sample catcher and ball check valve are in operating order, unless other types of sampler arrangements are specified by the Project Manager.

2) The boring shall be advanced to the bottom of last sample interval and a second sample attempt made after considering adjustments to the sampling technique for improving recovery. Adjustments may include:

   - The frequency of blows used to advance the sampler.
   - Letting the sampler "rest" after being driven the 18-inch sample interval.
   - Placing a plastic "sock" around the sample catcher.

- Pushing the sampler rather than driving with a hammer.
- Design of the catcher.
- Condition of the sampler shoe, replace if necessary.

3) If poor recovery continues, contact the Project Manager or refer to project- or site-specific directions.

There are a variety of samplers which may be used on drilling projects, each with its own purpose and advantages. Several of the most widely used samplers are described in Appendix B along with guidelines for their use. The Project Manager is responsible for selecting the sampling method(s) most desirable for the project.

8.3.3 Sample Logging

All samples, whether in situ or disturbed, shall be inspected and logged by the Geologist/Field Engineer. The soil shall be classified according to the procedures presented in TP-1.2-6, "Field Identification of Soil", and recorded on the Record of Borehole (Exhibit B).

For environmental soil samples, additional descriptions such as odor, staining, oily sheen, etc. should be noted on the log. Scanning the collected soils samples may also be done with and OVA, OVM or equivalent if volatile organics are present. These scan readings should be noted on the Record of Borehole at the corresponding depth.

8.3.4 Interim Sample Storage

Interim sample storage requirements shall be defined by the Project Manager and reviewed with the Geologist/Field Engineer prior to mobilization to the field. Unless otherwise directed by the Project Manager, minimum storage requirements shall be as follows:

- all environmental samples, in any type of container, shall be stored in an insulated cooler at 4°C;

- all environmental, permeability and moisture content samples shall be protected from freezing;

- all shelby tubes shall be sealed with paraffin, capped, and taped;

- all lexan inner liners shall be capped and taped, and shall be stored out of direct sunlight;

- all shelby tubes and lexan inner liners shall be stored vertically;

- all moisture-content samples shall be stored in airtight jars or double-bagged in plastic, with as much air as possible evacuated from the bags;

- all samples shall be stored in a safe place to preclude any loss or disturbance; and

- all environmental samples shall be stored in a locked storage area, or shall remain in view of the responsible Geologist/Field Engineer or sampler until transfer of chain-of-custody documentation and samples to the analytical laboratory. If it is necessary to keep the samples in a vehicle, the vehicle will be kept locked when unattended.

8.4 Abandonment of the Borehole

Boreholes shall be abandoned in compliance with applicable regulatory requirements, project work plans, or client requirements; abandonment methods and materials shall be defined by the Project Manager and shall be documented by the Geologist/Field Engineer on the History of Hole form (Exhibit B). If monitoring wells or piezometers are to be installed, refer to the applicable Golder Associates technical procedures and state regulations for further direction.

8.4 Capture and Disposal of Soil Drill Cuttings and Decontamination Solutions

Soil drill cuttings, contaminated groundwater and decontamination waste solutions produced during the drilling and sampling operations must be disposed of in accordance with Local State, and Federal regulations and shall be specified in the project work documents. Decontamination waste solutions that are generated during soil sampling include: spent detergent wash solutions; spent tap water rinses; any spent weak acid rinses, any spent methanol rinses; and spent final distilled/deionized water rinses. All spent acid and methanol rinses shall be captured and contained in plastic buckets or drums. Other spent decontamination waste solutions shall be captured and contained in appropriately sized buckets or drums, if a reasonable potential exists for the spent solutions to contain hazardous substances. Project work documents shall address or the Project Manager shall determine whether spent decontamination solution require capture and containment.

If required, decontamination waste solutions and contaminated soils shall be captured and contained in 55 gallon steel drums or suitable tanks. Liquid and solid waste should be segregated into separate containers. If required, each drum or tank shall be properly labelled with a weather proof label as to contents, borehole number, borehole interval contained in container, and date in which contents were generated. Storage and ultimate disposal of drums or tanks shall be specified in the project work documents or as directed by the Project Manager. Some noteworthy variances are as follows: (1) all acid solutions shall be neutralized with lime prior to discharge or disposal; (2) methanol solutions may be able to be evaporated, if segregated from other waste solutions, if generated in small enough quantities, and if conditions are favorable; and (3) if quantities are sufficiently small, decontamination waste solutions (detergent washes, rinse waters, neutralized acid solutions) may be added to the captured and contained soils that corresponds to the same soil sampling effort.

TABLE 1

SAMPLE CONTAINERS, PRESERVATION REQUIREMENTS, AND HOLDING TIMES FOR ENVIRONMENTAL SOIL SAMPLES

Contaminant	Container	Preservation	Holding Time
Acidity	P,G	Cool, 4°C	14 days
Alkalinity	P,G	Cool, 4°C	14 days
Ammonia	P,G	Cool, 4°C	28 days
Sulfate	P,G	Cool, 4°C	28 days
Sulfide	P,G	Cool, 4°C	28 days
Sulfite	P,G	Cool, 4°C	48 hours
Nitrate	P,G	Cool, 4°C	48 hours
Nitrate-Nitrite	P,G	Cool, 4°C	28 days
Nitrite	P,G	Cool, 4°C	48 hours
Oil and Grease	G	Cool, 4°C	28 days
Organic Carbon	P,G	Cool, 4°C	28 days
Metals			
Chromium VI	P,G	Cool, 4°C	48 hours
Mercury	P,G	Cool, 4°C	28 days
Metals except above	P,G	Cool, 4°C	6 months
Cyanide	P,G	Cool, 4°C	28 days
Organic Compounds			
Extractables (including phthalates, nitrosamines organochlorine pesticides PCB's nitroaromatics, isophorone, polynuclear aromatic hydrocarbons, haloethers, chlorinated hydrocarbons and TCDD)	G, teflon-lined cap	Cool, 4°C	7 days (until extraction) 30 days (after extraction)
Extractables (phenols)	G, teflon-lined cap		
Purgeable (halocarbons and aromatics)	G, teflon-lined septum	Cool, 4°C	14 days
Purgables (acrolein and acrylonitrate	G, teflon-lined septum	Cool, 4°C	3 days
Orthophosphate	P,G	Cool, 4°C	48 hours
Pesticides	G, teflon-lined cap	Cool, 4°C	7 days (until extraction)
Phenols	G	Cool, 4°C	28 days
Phosphorus	G	Cool, 4°C	48 hours
Phosphorus, total	P,G	Cool, 4°C	28 days
Chlorinated organic compounds	G, teflon-lined cap	Cool, 4°C	7 days (until extraction) 30 days (after extraction)

P = polyethylene
G = glass

Source: USEPA Soil Sampling Quality Assurance User's Guide, 2nd Edition, USEPA/600/8-89-046

Golder Associates

HISTORY OF HOLE

Job No. __________ Sheet ____ of ____

Geologist __________ Date __________ Boring No. __________

Driller __________ Surface Elevation __________ Weather __________ Temp ____ °F

Contractor __________ Drill Fluid __________ Depth __________ to __________

Location __________ Type of Barrel __________ Casing Size __________ Core Size __________

BEGINNING OF SHIFT	END OF SHIFT
Time ____ Depth of Hole ____	Time ____ Hrs. Productive ____ Hrs. Delayed ____
Depth to W. ____ Depth to Casing ____	Depth of Hole ____ Depth of Casing ____ Depth to W. ____

Checked by:

\forms\lot\023c.dwg

RECORD OF BOREHOLE

SHEET   OF

STA.   OFFSET   L R   ELEVATION   DATUM
PROJECT NO. 863-1604   SR-504   DRILLING DATE   DRILL RIG
INCLINATION   AZIMUTH

DEPTH SCALE (FEET)	BORING METHOD	SOIL PROFILE		SAMPLES				SAMPLE DESCRIPTION	NOTES — PIEZOMETER — STANDPIPE INSTALLATION
		SOIL PROFILE DESCRIPTION	GRAPHIC LOG	USCS	NUMBER	TYPE	BLOWS/ 6 IN	RECOVERY		

DEPTH SCALE
DRILLING CONTRACTOR
DRILLER

Golder Associates

LOGGED BY
CHECKED
DATE

SAMPLE INTEGRITY DATA SHEET

Plant Site ______________________ Project No. ______________

Site Location ______________________ Sample ID ______________

Sampling Location ______________________________________

____

Technical Procedure Reference(s) __________________________

Type of Sampler ____

Date ______________________ Time ______________________

Media ______________________ Station ____________________

Sample Type: grab time composite space composite

Sample Acquisition Measurements (depth, volume of static well water and purged water, etc.)

____

____

____

Sample Description ______________________________________

____

____

Field Measurements on Sample (pH, conductivity, etc.) ______________

____

____

____

Aliquot Amount	Container	Preservation/Amount

Sampler (signature) ______________________ Date ______________

Supervisor (signature) ______________________ Date ______________

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CHAIN OF CUSTODY RECORD

PROJ NO	SITE/LOCATION
SAMPLERS (Signature)	

STA NO.	DATE	TIME	SAMPLE TYPE	MEDIA	SAMPLE IDENTIFICATION	NO OF CONTAINERS	AMOUNT/ PRESERVATIVE						SEAL NO	SEAL INTACT? (Y/N)	REMARKS (with initials)

Relinquished by: (Signature/Firm)	Date/Time	Received by: (Signature/Firm)	Relinquished by (Signature/Firm)	Date/Time	Received by (Signature/Firm)
Relinquished by: (Signature/Firm)	Date/Time	Received by: (Signature/Firm)	Relinquished by (Signature/Firm)	Date/Time	Received by (Signature/Firm)
Relinquished by: (Signature/Firm)	Date/Time	Received by: (Signature/Firm)	Date/Time	Remarks (attachments if necessary)	

Golder Associates

Location ____________________
Job No.________ Date ________
Boring No.______ Sample No.______
Depth ________ Blows ________
Description__________________
____
____
____
Driller ________ Engr ________

GEOTECHNICAL SAMPLE LABEL

Golder Associates Seal Number 2455	Sent By: __________ Date. __________

Tamper Proof Seal

PROCEDURE ALTERATION CHECKLIST

Job/Task Number: ____________________

Procedure Reference: ____________________

Requested Variation: ____________________

Reason for Variation: ____________________

Special Equipment, Material or Personnel Required: ____________________

Alteration Requested By: ____________________ Date: __________

Title: ____________________

Reviewed By: ____________________ Date: __________

Title: GAI Project Manager

Comments: ____________________

Reviewed By: ____________________ Date: __________

Title: GAI QA Manager

Comments: ____________________

APPENDIX A

DRILLING METHODS

1. GENERAL DRILLING CONSIDERATIONS

Many types of drilling techniques exist for advancing boreholes in unconsolidated deposits. The methods described below include the hollow stem auger method, air rotary drill and drive, and cable tool drilling methods. This list is not intended to be all inclusive Unconsolidated deposits present special drilling problems due to the nature of the material, and the Project Manager shall determine the most appropriate drilling technique for the types of materials expected to be encountered The drilling method selected shall provide a reasonable opportunity to notice gross material changes and to make periodic depth soundings at the point at which the phreatic ground water level is encountered. Borehole instability or the tendency of the hole to collapse is common to all drilling methods in unconsolidated deposits.

All drive casing used in the drilling operation shall be of such design and wall thickness as to prevent collapse or deformation when driven through the in situ materials. All welding of drive casing or alternate approved methods of joining the casing shall follow acceptable practices to prevent separation at joints. If welding is employed, all welds shall have a minimum of three passes made on the weld joint and have a minimum of three "star welds."

For environmental investigations and the collection of environmental soil samples, some care must be exercised in the selection of the drilling method to insure representative samples. Grease or oil based lubricants may not be used on any drilling equipment that enters the borehole. Drill rigs must be adequately cleaned and decontaminated prior to setting up on each borehole. Any water introduced into the borehole during the drilling operation must be from an approved source and additional drilling additives will generally not be used. Compressed air used during air rotary drilling may need to be filtered depending on the analyte of concern.

2. METHODS

2.1 Hollow Stem Auger Method

The hollow stem auger method consists of advancing continuous flight augers into the ground. The terminal flight section is equipped with a drill bit or cutting teeth. In situ soils are sampled through the center of the hollow stem. Drill cuttings are brought to the surface by the "screw conveyor" action of the auger flights. Borehole stability is established by the augers. The maximum depth of penetration is usually 100 ft., although 160 to 180 foot drilling depths have been achieved in certain geologic materials. Auger flights are joined by clamping pins or by screw fittings. Grease shall not be used on the joints for lubrication if the particular project is an environmental investigation.

2.2 Air Rotary Drill and Drive

The air rotary drill and drive technique employs a tri-cone roller bit, pneumatic downhole hammer, or both, on drill rods to achieve penetration. Steel drive casing (usually 0.25 inch minimum wall thickness) is advanced for borehole stability directly behind the bit/hammer by driving with a pneumatic casing hammer. The drive casing is connected either by welding or flush coupled threaded joints. The terminal end of the drive casing is equipped with a hardened steel drive shoe for strength during penetration. Drill cuttings are removed from the borehole by circulating high volume compressed air to the bottom of the borehole through the drill rods and blowing the cuttings to the surface within the annular space between the rods and casing. On environmental investigations the air from the compressor must be filtered to remove the entrained oil before downhole use. In situ soils may be sampled through the drive casing after the bit/hammer and drill rods are removed from the borehole. Maximum depths for this drilling method depend of the size of the rig and compressor, but are normally greater than 300 feet. Air rotary drilling is not recommended for volatile organic sampling due to the "air stripping" action of the drilling operations.

2.3 Cable Tool Drilling

Cable tool drilling is slow, but offers some advantages for sampling. The technique employs a heavy downhole chopping bit which is dropped onto the underlying sediments to loosen the materials. The bit is connected to the drill rig by a wire (cable) line. The drill rig activates the up and down action for the bit. Steel drive casing (usually 0.25 inch minimum wall thickness) is advanced for borehole stability directly behind the downhole bit. The casing is driven by a hammer and anvil using the same up and down action of the drill rig. The steel drive casing sections are connected either by welding or flush coupled threaded joints. The terminal end of the drive casing is equipped with a hardened steel drive shoe for strength during penetration. Cuttings are allowed to accumulate until they start to lessen the impact of the bit and then are removed with a sand bailer or sand pump. In situ soils are sampled through the drive casing after the bit is removed from the borehole. It is necessary to add water to the borehole in the vadose zone for bailing cuttings from the hole. In environmental investigations, the composition of the added water must be known, particularly with regard to the analytes of concern.

APPENDIX B

SAMPLING METHODS

1. SPLIT-BARREL METHOD

1.1 Sampling Equipment Requirements

- split-tube samplers constructed in accordance with ASTM-D-1586, "Penetration Test and Split-Barrel Sampling of Soils" (see Figure B-1); 2, 4, and 6 inch diameter samplers should be available; all samples shall be fitted with hardened drive shoes and basket retainers.

- drive weight assembly constructed in accordance with ASTM-D-1586, affixed to a length of drill rod for advancing the sampler

- stainless steel spatulas

- sample containers as required

- sand catch or trap (optional)

- lexan inner barrel liners, caps, and tape, as required

1.2 Method

The sampling horizon may be exposed by any drilling technique that will produce suitable wall clearance for insertion of the sampler. Depth to the sample horizon shall be measured using the combined lengths of the downhole tools, drill rod or auger flight lengths, and amount of stickup above the drill collar. Particular attention must be paid to the calculated depth to ensure that the sampler is resting on the desired sample interval. Sampler diameter selection shall be based on geologic logging observations. 2-inch diameter samplers are appropriate for nonlithified clays, silts, sands and fine gravels; 4- or 6-inch samplers shall be selected for zones with coarse gravels and cobbles, or when larger sample volumes are required. Samplers shall be driven 18 inches with the drive weight (noting the weight of the hammer being used); blow counts for the first 18 inches of penetration shall be recorded in 6-inch increments, counted, and recorded on the Borehole Log. The downhole bit or auger, the split tube sampler and any liners and the stainless steel spatula shall be decontaminated prior to use.

2. THIN-WALLED ("SHELBY") TUBE SAMPLING METHOD

2.1 Sampling Equipment Requirements

- thin-walled metal sample tubes, manufactured in compliance with ASTM-D-1587, "Standard Practice for Thin-Walled Tube Sampling".
- aluminum foil or teflon sheeting, tube end caps, tape or seals, as required
- sample containers, as required
- stainless steel spatulas, if contents of tube are examined and transferred to sample containers at the surface prior to transfer to the laboratory
- wax or parrafin

2.2 Method

This method is normally used to obtain undisturbed samples of cohesive soils for geotechnical analysis, although thin walled sampling techniques (commonly referred to as Shelby tube techniques) may be used to sample other cohesive materials such as sludges for environmental assessments. Sampling methods should be in general accordance with ASTM-D-1587, "Standard Practice for Thin-Walled Tube Sampling of Soils." Any drilling technique is acceptable to expose the sampling horizon provided that sufficient clearance is present to permit insertion of the sampling equipment. Depth measurements shall be based on cumulative measurements of drill rods or auger flights, downhole tool length, and amount of stick up at the drill collar. Particular attention must be paid to the depth calculations to ensure that the sampler is resting on the desire sample interval. The sample tube is attached to an appropriate Shelby head subassembly, which is then connected to the drill rods, or auger flights, inserted to a maximum of 15 tube diameters by steady pressure with no rotation. Depending upon soil conditions the tube will be left in place for a period of time (5-10 minutes) to dissipate negative pressure prior to withdrawal of the tube. Depending on project-specific requirements, the sample tube may be capped labeled and sealed at the surface and routed directly to the laboratory. Alternately, the sample may be exposed at the surface, removed with a stainless steel spatula and transferred to a suitable container after visual examination. The downhole drilling tool, insertion tool, sample tube, and stainless spatula shall be decontaminated prior to use.

3. DRIVE TUBE (RING-LINED BARREL OR "CALIFORNIA") SAMPLING METHOD

3.1 Sampling Equipment Requirements

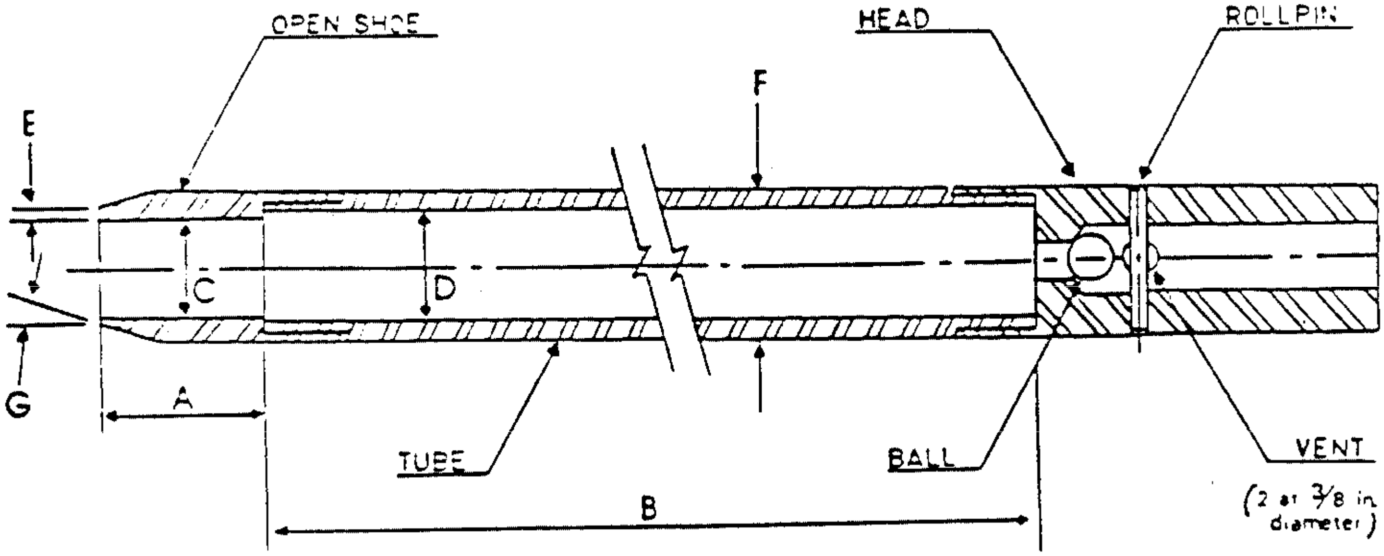
- drive tube (ring-lined barrel) assembly manufactured in compliance with ASTM-D-3550, "Ring-Lined Barrel Sampling of Soils" (see Figure B-2)
- sampler barrel with removable rings
- surface or downhole drive weight assembly
- stainless steel spatulas
- sample containers as required
- sand catch or trap (optional)
- inner barrel liners, aluminum foil or teflon sheeting caps, and tape, as required

3.2 Method

This method is normally used to obtain relatively undisturbed geotechnical samples, although this technique is useful in obtaining samples when volatile organic compounds are among the analytes of concern.

The sampling horizon may be exposed by any drilling technique that will produce suitable wall clearance for insertion of the sampler. Depth to the sample horizon shall be measured using the combined lengths of the downhole tools, drill rod or auger flight lengths, minus the amount of stick up above the drill collar. Particular attention must be paid to the depth calculations to ensure that the sampler is resting on the desired sample interval. Samplers shall be driven 18 inches with a surface or downhole drive weight assembly (noting the weight of the hammer being used); sampler insertion should be by pushing in lieu of driving wherever possible. If required by project-specific requirements, blow counts of the first 18 inches of penetrations shall be counted and recorded in 6-inch increments on the Borehole Log. The sampler shall be retrieved and carefully disassembled. Trim the soil flush with the sampling barrel with the spatula, and remove the specimen-filled rings. Place each ring in a suitable container and cap and seal with clean aluminum foil at both ends. Downhole samplers and stainless steel spatulas shall be decontaminated prior to use.

(From ASTM-D-1586 "Penetration Test and Split-Barrel Sampling of Soils")

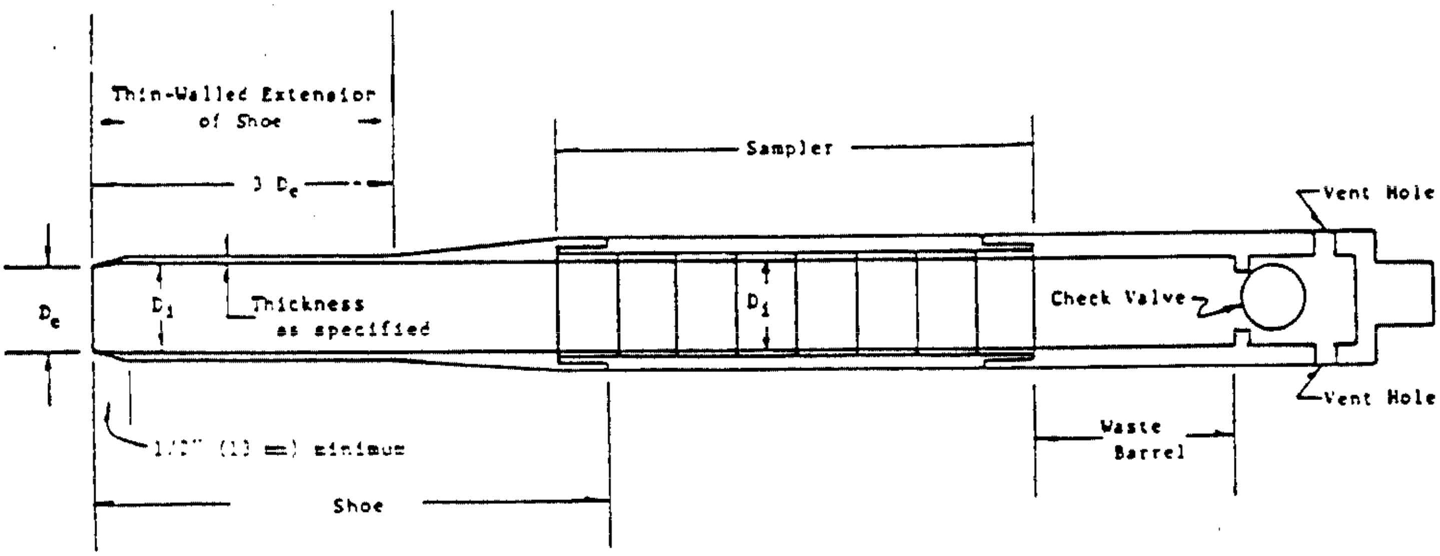


A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 − 0.00 in. (38.1 ± 1.3 − 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 − 0.00 in. (50.8 ± 1.3 − 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

(From: ASTM-D-3550, Standard Practice For Ring-Lined Barrel Sampling of Soils)



NOTE 1—Inside clearance ratio = $(D_i - D_e)/D_e$

NOTE 2—Dimensional tolerance of D_e = ±0.003 in. (±0.08 mm)

APPENDIX F

TP-1.2-6. Technical Procedure
Field Identification of Soil

RECORD OF REVISIONS

Revision	Page	Section	Description of Change
6	Throughout		Editorial and format changes
6	2	8.1	Removed reference to the Burmister System
6	3	8.3	Deleted reference to Munsell Color Chart
6	3 3 4 10 10 10 10	8.4.3 8.4.4 8.4.8 8.7.5 8.7.6 8.7.8 8.7.9	Revised definitions and terminology
6	Tables		Tables were created from information previously located in text
6	Table 3		Pertinent information was extracted - now located in Figure 1.

1. PURPOSE

This technical procedure describes uniform procedures for identification of soils.

2. APPLICABILITY

This technical procedure is applicable to all persons engaged in soils identification.

3. DEFINITIONS

Definitions are contained within Section 8.

4. REFERENCES

ASTM Standards, 1979, Standard Recommended Practice for Description of Soils (Visual-Manual Procedure), D 2488-69, American Society for Testing and Materials, Philadelphia, Pennsylvania.

Rock-Color Chart, Geological Society of America, Boulder, Colorado.

5. DISCUSSION

Soil identification techniques are employed to characterize and describe soil for geologic and hydrologic interpretation, foundation engineering, well screen sizing, and a wide range of other purposes.

6. RESPONSIBILITY

Each individual designated responsibilities for soil identification shall utilize this procedure.

7. EQUIPMENT AND MATERIALS

- Supply of water
- Pocket knife or small spatula
- Small test tube with stopper or glass jar with sealed lid
- Small hand lens
- Pocket penetrometer or shear gage
- One-half-inch (12 mm) rebar

- Five-pound hammer
- Notebook
- Exploration logs

8. PROCEDURE

8.1 General

The recommended Soils Classification System is based on the Unified Classification System as summarized on Figure 1.

The soil description involves the following general format: 6

(1) Consistency or Density, (2) Color, (3) Structural Characteristics, (4) Composition with Major Component in Capital Letters, (5) Minor Char., (6) Geologic Description in Capital Letters

Thus, for example, a typical description might include:

Stiff, Grey, stratified, SILTY CLAY, trace Sand, slickensides, (LACUSTRINE)

The following sections discuss the different elements (1-6 above) of the soil description.

8.2 Determination of Consistency or Relative Density

8.2.1 N-Values

The standard penetration test (SPT), or number of blows required by a 140-pound hammer or weight dropped 30 inches to drive a two-inch O.D. (1 3/8-inch ID) drive-open sampler, will indicate the relative density of cohesionless soils and the consistency of cohesive soils. The standard tests penetrates 18 inches. N values are the blows required to drive the sampler the last 12 inches. The blows required to drive the sampler the first six inches are normally not taken into account unless one or both of the subsequent blow counts are affected by gravel of cobbles. Blows are recorded for each six-inch interval. The relative density or coarse-grained soils is shown in Table 1.

8.2.1.1 Relative Density of Granular Soils

The relative density modifiers given in Table I for coarse-grained soils should also be used for fine-grained non-plastic soils described predominately by SILT.

8.2.1.2 Consistency of Fine-Grained, Cohesive Soils

Shown in Table 2 are criteria for the quantitative and qualitative determination of the consistency of fine-grained, cohesive soils. The criterion based on N-Values is considered unreliable and should be used with caution. The criterion based on undrained shear strength may be used when values of undrained shear strength are available. The field identification test is simple and reliable and is the method which can be used in most instances.

8.3 Determination of Color

Color can be an important property in identifying materials of similar
geologic origin and in identifying organic soils. Although qualitative color
names are somewhat helpful, positive color identifications obtained by
comparison with a standard color chart are even more useful. If the sample
contains layers or patches of varying colors, this should be noted and all
representative colors should be described for moist samples. If possible,
color should be described for moist samples. The Geologic Society of America
Rock-Color Chart should be used to identify color. Provide both the color
name and chromal hue symbols in soil descriptions. Mottled soils show the 6
presence of spots, streaks, or splotches of one or more colors in a soil mass
of another predominant color. In mottled soils, the colors are not mixed and
blended, but each is more or less distinct in the general ground color.

8.4 Definitions of Structural Characteristics

8.4.1 Stratified

Composed of, or arranged in, layers. The layers are parallel to one another, and composed of soils visibly different from each other.

8.4.2 Parting

Paper-thin separation of one soil type within another. Usually applied to cohesive soils.

8.4.3 Rhythmic

Consisting of alternative thin layers of sand, silt or clay. Each layer
generally less than one-half-inch in thickness. Lacustrine deposits with
annual layers are termed varves or are said to be varned. 6

8.4.4 Lenses

A particular soil type significantly different from the surrounding soils which thins out laterally is said be a lens or be lens-shaped.

8.4.5 Pocket

A different soil type of limited thickness and lateral extent.

8.4.6 Homogenous

Of uniform structure.

8.4.7 Heterogenous

Consisting of dissimilar constituents, mixed.

8.4.8 Slickensided/Polished/Scratched Surfaces

A polished and scratched surface that results from friction of one block of material moving relative to another block. Polished and/or scratched surfaces may be related to minor movement along discontinuities or may be related to faults and termed slickensides. 6

8.4.9 Fissured

This term applies to hard, over-consolidated silts and clays and refers to physical discontinuities such as fissures and cracks that formed during or after consolidation. The abundance and character of the fissuring can be described as follows:

"Highly Fissured" - Fractures are spaced one-half-inch or closer over most of the interval described.

"Moderately Fissured" - Sample contains two or more fractures or thin fracture zones per six-inch sample, but average spacing is wider than one-half inch.

"Locally Fissured" - Only one fracture or narrow (less than three inches) fracture zone is observed in a sample.

Fissuring characteristics that can be noted and/or described include attitude, length, width, aperture (closed, tight, open), staining/infilling, roughness, curvature, continuity, slickensides, polish, gouge, relation to other structures and other distinguishing features.

8.5 Determination of Soil Composition

8.5.1 General

For purposes of soil description, the material is considered to be composed of the coarse fraction or of particles larger than the No. 200 sieve (+.074 mm) and the fine fraction or those smaller than the No. 200 sieve. The coarse fraction is described based on its particle size while the fines are described on its plasticity.

The following terminology is used to denote the percentage by dry weight of each soil component:

Descriptive Term	Range of Proportion
Trace	0-5%
Little	5-12%
Some or Adjective*	12-30%
And	30-50%

*Adjective: silty, sandy, gravelly, etc.

For example: "SILT, some Sand, trace Gravel" describes a basic soil component of silt (30-50 percent), with minor components of sand (12-30 percent), and gravel (0-5%).

Soils are to be described according to the following criteria with the principal constituents written in capital letters. Other constituents are preceded by descriptive terminology that is used to denote the percentage by weight of each component. Soil descriptions are determined visually except where laboratory classification test data are available. The following abbreviations are acceptable:

c = coarse
m = medium
f = fine

8.5.2 Field Indication Tests - Fines

8.5.2.1 Fine-Grained Soil Descriptions

The description of fine-grained soil components (i.e., passing the No. 200 sieve or smaller than 0.074 mm) is based on plasticity and not grain size. Thus, terms like SILT, trace Clay or Silt, little Clay are not used. Rather, the terms, SILT, CLAYEY SILT, SILTY CLAY, and CLAY are applied to the fine-grained component as a whole. Their characteristics are described in Table 4.

8.5.2.2 Field Test for Plasticity

Plasticity refers to the ability of a material to be deformed rapidly without cracking or crumbling and then maintain that deformed shape after the deforming force has been released. A soil is said to be highly plastic if there is a wide range of moisture content over which it remains in the plastic state. High plasticity indicates a high clay content. Identification of cohesive soils in relation to their plasticity can be made on the following basis: The natural soil is worked until its moisture content is such that a 1.5-inch diameter ball formed from the soil shows a flattened contact surface of 7/8-inch diameter when dropped from a height of two feet (gravel sizes are not included in the ball). The smallest thread possible without crumbling is then rolled from the above soil sample. The approximate relationships below are then used for identification:

Thread Diameter	Descriptive Term
1/4-inch	SILT
1/8- to 1/16-inch	CLAYEY SILT
1/32-inch	SILTY CLAY
1/64-inch	CLAY

8.5.2.3 Dry Strength

A portion of the soil is allowed to dry out completely in air. An angular fragment (about one-half-inch) of the dried soil is pressed between the fingers. The dry strength of the fragment is expressed as very low, low, medium, high and very high. Fragments with very high strength cannot be injured at all, whereas, those of very low strength disintegrate completely on gentle pressure. The strength is called medium if the fragment can be reduced to powder only with great effort. Those materials with greater dry strengths are predominately clayey, and those with less dry strength are predominately silty.

8.5.2.4 Stickiness

A high degree of stickiness in the natural state is indicative of higher plasticity.

8.5.2.5 Shine Test

If a moist lump of soil is stroked with considerable pressure with the flat of a pen knife blade or fingernail, the type of surface imparted is an indication of the soil. If a shiny surface results, the presence of clay is indicated. Silt is indicated if a dull surface is produced.

8.5.2.6 Grittiness Test

THIS TEST SHOULD NOT BE PERFORMED WHEN HAZARDOUS WASTE CONTAMINATION IS SUSPECTED OR KNOWN TO BE PRESENT. In other cases, when a small amount of the uncontaminated soil is placed between the teeth, the presence of grit will indicate silt or sand, but if no grit is detected, a pure clay is present.

8.5.3 Field Identification Tests - Organic Soils

8.5.3.1 Organic Soil

Description of organic soils depends on the percentage and distribution or organics in the soil. If the soil matrix is inorganic with occasional pieces or organic matter, this can be described under <u>Minor Characteristics</u>.

If the soil is primarily inorganic, but contains a significant amount of organic, the modifier organic can be used. If the soil is primarily organic, then it should be called a Peat. Examples include:

- Silty SAND, occasional organic matter
- Organic SILT
- Sandy PEAT

Table 5 includes a system for classifying organic soils.

8.5.3.2 Organic Cohesive Soils

Organic cohesive soils display the following characteristics.

- A dark-brown, dark-gray, black color indicates the presence of organic matter.
- An odor of decaying vegetation is typical. If organic matter cannot be distinguished, it can sometimes be brought out by a small amount of heat.
- The presence of fibrous or root structures, twigs, leaves or shells is common.
- At least a three-quarter reduction in the liquid limit value after oven-drying is considered positive identification of organic soil.
- The plasticity of fine-grained organic soils is greatly reduced on oven-drying due to irreversible changes in organic colloids.
- Organic clays feel spongy in the plastic range as compared to inorganic clays.

8.5.3.3 Organic Soil - Peat

Peat is usually dark brown to black; contains fibrous particles of vegetation in varying states of decay; has characteristic organic odor; is usually spongy and compressible; commonly contains natural moisture contents of over 100 percent and can contain organic and inorganic silts and clays in varying amounts and concentrations.

8.5.4 Field Identification Tests - Cohesionless Soils

8.5.4.1 Visual Identification of Grain Size

The constituent parts of a soil sample are defined by grain size, as indicated in Table 3.

8.5.4.2 Grittiness Test

THIS TEST SHALL NOT BE PERFORMED WHEN HAZARDOUS WASTE CONTAMINATION OF THE SOIL IS SUSPECTED OR KNOWN TO BE PRESENT.

The soil is handled lightly between the thumb and forefinger to get an idea of the grittiness or softness of the soil. A pinch of uncontaminated soil is smeared with considerable pressure between the thumb and forefinger to determine the degree of harshness and grittiness. When a small amount of uncontaminated soil is placed between the teeth, the presence of grit will indicate silt or sand, but if no grit is detected, an almost pure clay is present.

- Coarse to medium sand exhibits a typically harsh and very gritty smear.
- Coarse to fine sand has a less harsh feel, but exhibits a very gritty smear.
- Medium to fine sand exhibits a less gritty feel and smear.
- Fine sand has a softer feel and much less gritty smear.

8.5.4.3 Test Tube Test

A small sample of the soil (lumps are first broken up) is shaken in a test tube or glass jar filled with water and is allowed to settle. All the fine sand will settle out (four-inch fall) in 30 seconds; the silt in 50 minutes. A rough idea of the grain sizes can be obtained by this test.

8.5.4.4 Dilatancy Test

When a wet pat of soil is shaken vigorously in the hand, the surface will become glassy and show free water. If the pat of soil is then squeezed in the fingers with free water disappearing and the surface becomes dull, the soil is NOT a clay soil, but a silt or fine sand. If the free water on the surface disappears immediately (as walking on the beach adjacent to the water), the soil is most likely a fine sand. If the free water tends to ooze away, the soil is most likely silt.

8.5.5 Determination of Soil Types

Based on the tests and observations described in the previous text, the soil description can be made by compiling the properties of the soil and comparing them to Table 2.

8.6 Minor and/or Usual Characteristics

8.6.1 General

Minor characteristics of the soil sample should be included in its description. These characteristics include occasional traces of organic debris, mention of other types of deleterious materials such as a trash or cinder fill, portions of cobbles or boulders received in the sampler, and pockets and/or lenses of material other than those already mentioned in the description. A minor constituent, such as gravel, which is part of the overall soil matrix, would be described using the modifiers presented in 8.5.1.2 (i.e., trace, little, etc.). In some cases, a minor constituent is scattered throughout the unit and is not part of the matrix. In this case, it would not be described as a minor characteristic. An example would be a lacustrine clay with ice rafted pebbles. Thus, the soil would be described as SILTY CLAY, scattered pebbles, and not SILTY CLAY, little gravel.

8.6.2 Determination of Moisture Content

Moisture descriptions should not generally be used and can be misleading. A general qualitative description can be applied if necessary. The following descriptions can be used:

- Dry: No discernable moisture present.
- Damp: Enough moisture present to darken the appearance, but no moisture on materials adheres to the hand.
- Moist: Will moisten the hand.
- Wet: Visible water present; plastic materials will leave sticky residue in hand when remolded.

As an example, hard clays often appear dry, but may be saturated even above the water table. However, in soft soils or granular soils, the moisture content can be relevant.

8.7 Definitions of General Geologic Descriptions

Generally, a geologic term, in capital letters, should be applied to major soil units, if appropriate. However, in many cases, there is inadequate information to determine a precise geologic description. In these cases, the term "possible" can be applied (i.e., possible TILL).

As appropriate, specific geologic names such as Lawton Clay can be used. However, when used, there should be sufficient specific geologic evidence of the name designation. If in doubt, do not use specific name or add "possible."

8.7.1 Fill

Material placed by humans.

8.7.2 Peat or Organic Matter

Natural deposit composed primarily of organic matter.

8.7.3 Lacustrine Deposits

Deposited in lakes.

8.7.4 Alluvial Soil

Any soil that has been deposited by a stream. Such soils usually contain some sand and rounded gravel or cobbles.

8.7.5 Till

A nonstratified random mixture of clay, silt, sand, gravel and boulders deposited by glaciers. Alternating layers of clayey till and till containing boulders are possible. 6

8.7.6 Outwash

A stratified alluvial soil transported and deposited by a glacial meltwater stream.

8.7.7 Loess

A uniform aeolian (wind) deposit of silty material having an open structure and relatively high cohesion due to a clay matrix or cementation by calcareous material at grain contacts. A characteristic of loess deposits is that they display nearly vertical slopes.

8.7.8 Pedogenic Soils

Soils that have formed in place due to decomposition of rock. Shales form residual clays. Limestones form lean brown and fat red clays. Granitic rocks form silty sand with angular sand grains.

8.7.9 Colluvial Soil 6

A nonstratified mixture of angular sand, gravel and boulder size material accumulated at the foot of a slope or on the slope itself chiefly under the influence of gravity.

8.8 Reaction To Dilute Hydrochloric Acid

Some soils show definite evidence of cementation in the intact state. Where this is noted, the degree of cementation may be described as weak or strong. Since calcium carbonate is the most common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important. The intensity of the HCl reaction should be described as none (NR), weak (WR), or strong (SR).

8.9 Unified Symbols

The Unified Classification System symbols should be indicated on the final boring and test pit logs. These symbols are based on soil groupings as shown on Figure 1.

8.10 Report Format

The boring logs used in the report should conform to the general format shown on the attached example boring log, Figure 2. In addition to the logs, all reports should include the Classification System as shown in Tables 1 through 6. Some specific comments on the final boring log include:

- ACTUAL BLOW COUNTS: The actual blow count raw data shall be shown on the logs; i.e., blows per six inches.

- UNIFIED SYMBOL: A column will be used to show the Unified Symbol for the soil.

- PENETRATION/RECOVERY: The amount of sample penetration and recovery will be shown on the log.

- COLUMN FOR LAB TESTS: The locations of all lab tests (except for water contents and Atterberg limits which are shown graphically) should be indicated in shorthand as shown on the Sample Log and on Figure 1.

- SOIL CONTACTS: Under "Description" on Figure 2, horizontal solid and dashed lines are used to represent soil contacts. Solid lines represent soil contacts between major units; dashed lines represent gradation contacts within the same major unit. Inclined lines in the "USCS Class" column represent uncertainty of the depth of actual soil contact.

- TYPED: Logs shall be typed and not hand-lettered unless requested by the client.

- PLOTTING OF BLOW COUNTS AND MOISTURE CONTENTS: All logs shall include a disclaimer relating to these plots due to the liability associated with interpretations that could be applied to these graphs.

TABLE 1

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Relative Density	N, Blows/Foot*	Field Identification
Very Loose	0-4	Easily penetrated with shovel handle.
Loose	4-10	Easily penetrated with 1/2-inch rebar pushed by hand. Easily excavated with hand shovel.
Compact	10-30	Easily penetrated with 1/2-inch rebar driven with five-pound hammer. Difficult to excavate with hand shovel.
Dense	30-50	Penetrated one foot with 1/2-inch rebar driven with a five-pound hammer. Must be loosened with pick to excavate.
Very Dense	>50	Penetrated only a few inches with 1/2-inch rebar driven with a five-pound hammer.

* Judgment required if soils contain gravel and cobbles since the "N" value may be unreliable in determining relative density.

TABLE 2

CONSISTENCY OF COHESIVE SOILS

Consistency	N (blows/ft.) (unreliable)	Undrained Shear Strength* (psf)	Field Identification
Very soft	0-2	Less than 250	Extrudes from between fingers when squeezed in hand.
Soft	2-4	250-500	Molded by light finger pressure.
Firm	4-8	500-1,000	Molded by strong finger pressure.
Stiff	8-15	1,000-2,000	Indented by thumb.
Very stiff	15-30	2,000-4,000	Indented by thumbnail.
Hard	Greater than 30	Greater than 4,000	Difficult to indent with thumbnail.

*Undrained shear strength equals one-half the unconfined compressive strength.

TABLE 3

COMPONENT DEFINITIONS BY GRADATION

Component	Size Range
Boulders	Above 12 inches in diameter
Cobbles	3 to 12 inches
Gravel	3 inches to No. 4 (4.76 mm)
Coarse Gravel	3 inches to 3/4 inch
Fine Gravel	3/4 inches to No. 4 (4.76 mm)
Sand	No. 4 (4.76 mm) to No. 200 (0.074 mm)
Coarse Sand	No. 4 (4.76 mm) to No. 10 (2.0 mm)
Medium Sand	No. 10 (2.0 mm) to No. 40 (0.42 mm)
Fine Sand	No. 40 (0.42 mm) to No. 200 (0.074 mm)
Silt and Clay	Finer than No. 200 (0.074 mm)

COMPONENT PROPORTION

Descriptive Term	Range of Proportion
Trace	0-5%
Little	5-12%
Some or Adjective*	12-30%

*Adjective: silty, sandy, gravelly, etc.

For example: "SILT, some Sand, trace Gravel" describes a basic soil component of silt (30-50 percent), with minor components of sand (12-30 percent), and gravel (0-5%).

TABLE 4

FINE GRAIN DESCRIPTIONS

Descriptive Term	Plastic Index*	Characteristics
SILT	Less than 2	Rapid pronounced response to shaking test, very low cry strength; has almost a granular appearance and feel; thread cannot be rolled or can only be rolled with great difficulty.
CLAYEY SILT	2-15	Noticeable response to shaking and squeezing test, but appreciably less pronounced than for silt; low medium dry strength; slightly sticky, slightly slick and smooth smear; can roll a thread easily.
SILTY CLAY	15-40	No response to shaking and squeezing test; medium to high dry strength; rather sticky when moistened; moderately slick and smooth smear; can roll a thread when moderately dry.
CLAY	Greater than 40	No response to shaking test; high to very high dry strength; slick and waxy, can roll a thread when quite dry.

*Plastic Index: Liquid limit minus plastic limit.

DESCRIPTION BASED ON FIELD TEST FOR PLASTICITY

Thread Diameter	Descriptive Term
1/4-inch	SILT
1/8- to 1/16-inch	CLAYEY SILT
1/32-inch	SILTY CLAY
1/64-inch	CLAY

TABLE 5

SOIL CLASSIFICATION FOR ORGANIC SOILS

Category	Name	Organic Content (% by wt.)	Group Symbols (See Table 3)	Distinguishing Characteristics For Visual Identification	Range of Laboratory Test Values
ORGANIC MATTER	FIBROUS PEAT (woody, mats, etc.)	75 to 100% Organics either visible or inferred	Pt	Light weight, spongy and often elastic at w_n—shrinks considerably on air drying. Much water squeezes from sample.	w_n--500 to 1200% γ—60 to 70 pcf G—1.2 to 1.8 $C_c/(1+e_o)$=.4+
	FINE GRAINED PEAT (amorphous)			Light weight, spongy but not often elastic at w_n—shrinks considerably on air drying. Much water squeezes from sample.	w_n--400 to 800% LL--400 to 900% PI--200 to 500 γ—60 to 70 pcf G—1.2 to 1.8 $C_c/(1+e_o)$=.35 to .4+
HIGHLY ORGANIC SOILS	Silty Peat	30 to 75% Organics either visible or inferred	Pt	Relatively light weight, spongy. Thread usually weak and spongy near PL Shrinks on air drying; medium dry strength. Usually can squeeze water from sample readily—slow dilatency.	w_n--250 to 500% LL—250 to 600% PI--150 to 350 γ—65 to 90 pcf G--1.8 to 2.3 $C_c/(1+e_o)$=.3 to .4
	Sandy Peat			Sand fraction visible. Thread weak and friable near PL; shrinks on air drying; low dry strength. Usually can squeeze water from sample readily—high dilatency—"gritty."	w_n—100 to 400% LL--150 to 300% (plot below A line) PI--50 to 150 γ—70 to 100 pcf G—1.8 to 2.4 $C_c/(1+e_o)$=.2 to .3
ORGANIC SOILS	Clayey ORGANIC SILT	5 to 30% Organics either visible or inferred	OH	Often has strong H_2S odor. Thread may be tough depending on clay fraction. Medium dry strength, slow dilatency.	w_n--65 to 200% LL--65 to 150% (usually plot at or near A line) PI— 50 to 150 γ—70 to 100 pcf G--2.3 to 2.6 $C_c/(1+e_o)$=.20 to .35
	Organic SAND or SILT		OL	Threads weak and friable near PL—or may not roll at all. Low dry strength; medium to high dilatency.	w_n—30 to 125% LL--30 to 100% (usually plot well below A line) PI--non-plastic to 40 γ—90 to 110 pcf G—2.4 to 2.6 $C_c/(1+e_o)$=.1 to .25
SLIGHTLY ORGANIC SOILS	SOIL FRACTION add slightly Organic	Less than 5% Organics combined visible and inferred	Depend upon inorganic fraction	Depend upon the characteristics of the inorganic fraction.	Depend upon inorganic fractions.

TABLE 6

DESCRIPTION OF SOIL BASED ON OBSERVATION AND TESTS

Typical Name	Description
BOULDERS	Larger than 12 inches in diameter
COBBLES	3 to 12 inches in diameter
GRAVEL	No. 4 sieve to 3 inches in diameter
Coarse to Fine SAND	No. 200 to No. 4 sieve sizes; all particles are visible to the naked eye

	Dilatancy Test	Test Tube Test	Plasticity	Dry Strength	Stickiness	Shine Test
fine SAND	rapid	30 sec	none	extremely	none	none
SILT	moderate	50 min	none	very low	none	none
SILT	slow	+50 min	slight	low	none	none
CLAYEY SILT	none	hours	medium	low to to high	slight	smooth & dull
SILTY CLAY	none	hours	high	medium to high	moderate to high	moderately slick & smooth
CLAY	none	+24 hrs	very high	high to very high	high to very high	slick & waxy
organic SILT	moderate	±50 min	slight to medium	low	none	dull & silky
organic CLAY	none	±24 hrs	medium to high	medium to high	moderate to high	dull, smooth & silky

Unified Soil Classification System

Criteria for Assigning Group Symbols and Names			Soil Classification	Generalized Group Descriptions
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve	GRAVELS More than 50% of coarse fraction retained on No. 4 Sieve	CLEAN GRAVELS Less than 5% fines	GW	Well-graded Gravels
			GP	Poorly-graded gravels
		GRAVELS WITH FINES More than 12% fines	GM	Gravel and Silt Mixtures
			GC	Gravel and Clay Mixtures
	SANDS 50% or more of coarse fraction passes No. 4 Sieve	CLEAN SANDS Less than 5% fines	SW	Well-graded Sands
			SP	Poorly-graded Sands
		SANDS WITH FINES More than 12% fines	SM	Sand and Silt Mixtures
			SC	Sand and Clay Mixtures
FINE-GRAINED SOILS 50% or more passes the No. 200 sieve	SILTS AND CLAYS Liquid limit less than 50	INORGANIC	CL	Low-plasticity Clays
			ML	Non-plastic and Low-Plasticity Silts
		ORGANIC	OL	Non-plastic and Low-Plasticity Organic Clays Non-plastic and Low-Plasticity Organic Silts
	SILTS AND CLAYS Liquid limit greater than 50	INORGANIC	CH	High-plasticity Clays
			MH	High-plasticity Silts
		ORGANIC	OH	High-plasticity Organic Clays High-plasticity Organic Silts
HIGHLY ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor		PT	Peat

Component Definitions by Gradation

Component	Size Range
Boulders	Above 12 in
Cobbles	3 in to 12 in
Gravel	3 in to No. 4 (4.76mm)
Coarse gravel	3 in. to 3/4 in
Fine gravel	3/4 in to No. 4 (4.76mm)
Sand	No. 4 (4.76mm) to No. 200 (0.074mm)
Coarse sand	No. 4 (4.76mm) to No. 10 (2.0mm)
Medium sand	No. 10 (2.0mm) to No. 40 (0.42mm)
Fine sand	No. 40 (0.42mm) to No. 200 (0.074mm)
Silt and Clay	Smaller than No. 200 (0.074mm)

Samples

SS	SPT Sampler (2.0" OD)
HD	Heavy Duty Split Spoon
SH	Shelby Tube
P	Pitcher Sampler
B	Bulk
C	Cored

Unless otherwise noted, drive samples advanced with 140 lb hammer with 30 in. drop

Relative Density or Consistency Utilizing Standard Penetration Test Values

Cohesionless Soils (a)			Cohesive Soils (b)		
Density (c)	N, blows/ft. (c)	Relative Density (%)	Consistency	N, blows/ft. (c)	Undrained Shear Strength (d) (psf)
Very loose	0 to 4	0 - 15	Very soft	0 to 2	<250
Loose	4 to 10	15 - 35	Soft	2 to 4	250-500
Compact	10 to 30	35 - 65	Firm	4 to 8	500-1000
Dense	30 to 50	65 - 85	Stiff	8 to 15	1000-2000
Very Dense	over 50	>85	Very Stiff	15 to 30	2000-4000
			Hard	over 30	>4000

(a) Soils consisting of gravel, sand, and silt, either separately or in combination, possessing no characteristics of plasticity, and exhibiting drained behavior.

(b) Soils possessing the characteristics of plasticity, and exhibiting undrained behavior.

(c) Refer to text of ASTM D 1586-84 for a definition of N; in normally consolidated cohesionless soils Relative Density terms are based on N values corrected for overburden pressures.

(d) Undrained shear strength = 1/2 unconfined compression strength

Laboratory Tests

Test	Designation
Moisture	(1)
Density	D
Grain Size	G
Hydrometer	H
Atterberg Limits	(1)
Consolidation	C
Unconfined	U
UU Triax	UU
CU Triax	CU
CD Triax	CD
Permeability	P

(1) Moisture and Atterberg Limits plotted on log.

Descriptive Terminology Denoting Component Proportions

Descriptive Terms	Range of Proportion
Trace	0-5%
Little	5-12%
Some or Adjective (a)	12-30%
And	30-50%

(a) Use Gravelly, Sandy or Silty as appropriate

Silt and Clay Descriptions

Description	Typical Unified Designation
Silt	ML (non-plastic)
Clayey Silt	CL-ML (low plasticity)
Silty Clay	CL
Clay	CH
Plastic Silt	MH
Organic Soils	OL, OH, Pt

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FIGURE 1

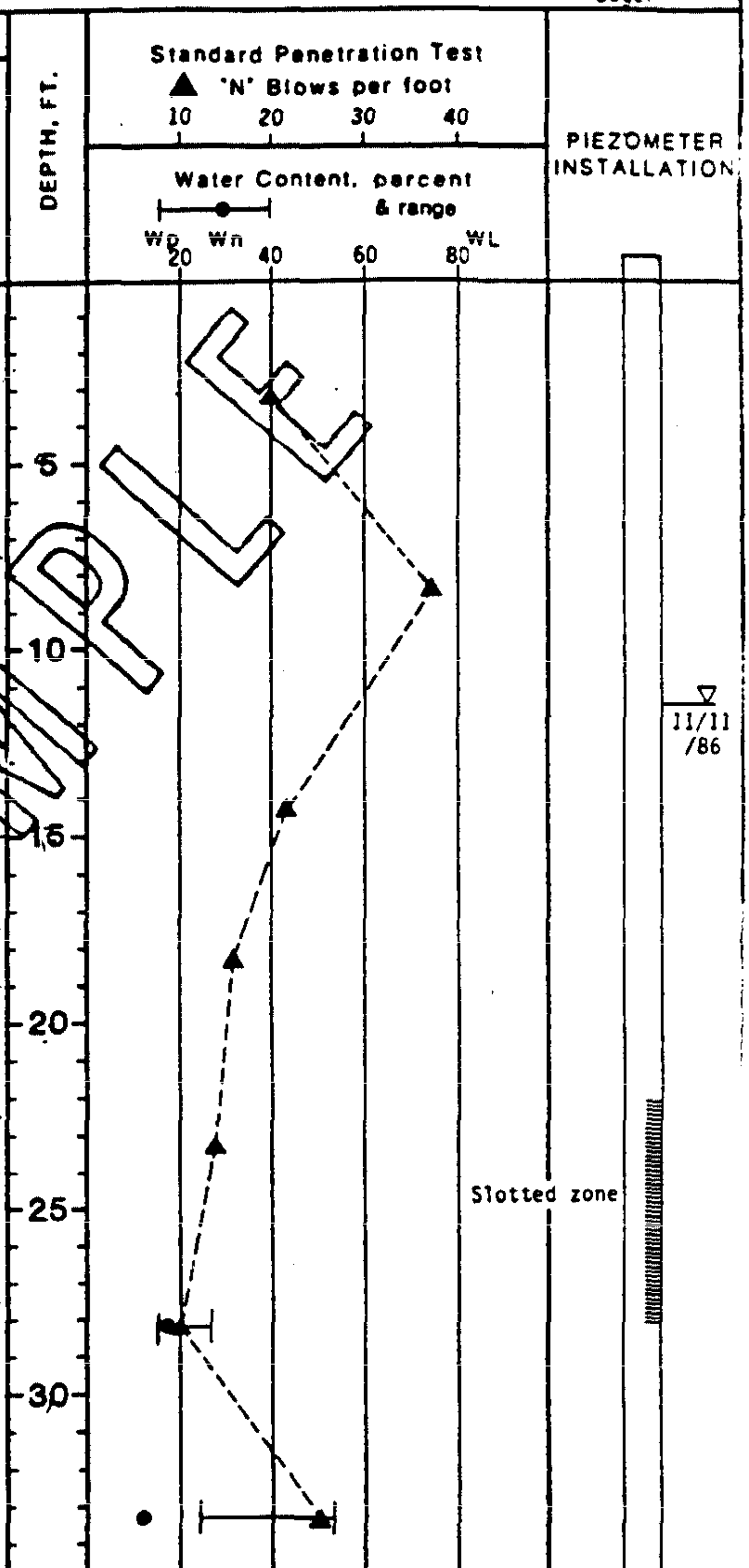
SOIL CLASSIFICATION/LEGEND

RECORD OF BOREHOLE BH-1

LOCATION: See Figure 2 | DATUM: 146 (estimated) | DATE: 10-30-86

SAMPLER HAMMER WEIGHT: 140 LB., DROP 30 IN. | BORING METHOD: Hollow stem auger

SOIL PROFILE			SAMPLES		
ELEVN / DEPTH	DESCRIPTION	USCS CLASS	NUMBER	TYPE	BLOWS/6"
146 0.0	Dark brown, organic, Sandy SILT (Topsoil)				
143 3.0	Compact, very stiff, brown, fine SAND and SILT		1	SPT	6 9 11
142 4.0	Dense, tan, fine Sandy SILT, little coarse Sand and Gravel (Weathered Till)	SM	2	SPT	12 18 20
			3	SH	N/A
132 14.0	Loose to compact, gray, CLAYEY SILT, little fine to coarse Sand and Gravel (Till)	ML	4	SPT	8 10 12
			5	SPT	4 7 10
			6	SPT	5 6 8
			7	SPT	3 4 6
116 30.0	Very stiff, gray, SILTY CLAY, trace coarse Sand and Gravel	CH CL	8	SPT	15 15 10



REMARKS: SPT = Standard penetration test.
SH = Shelby tube sample

DISCLAIMER: Dotted lines connecting test results are intended for clarity only and do not imply any distribution.

VERTICAL SCALE:
1 IN. TO 5 FT.

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TP-1.2-6